



THE SAN FRANCISCO-OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECTS

CALTRANS

BAY AREA TOLL AUTHORITY

CALIFORNIA TRANSPORTATION COMMISSION

Memo

April 24, 2013

Re: Bay Bridge E2 Connector Rods Investigation UPDATE

Members of the Toll Bridge Program Oversight Committee (TBPOC) on Wednesday delivered their third public briefing since 32 large bolts broke during construction of the San Francisco-Oakland Bay Bridge's new East Span.

The TBPOC was established by state statute to oversee seismic construction projects of Bay Area bridges, most notably the San Francisco-Oakland Bay Bridge. The TBPOC provided details about what caused the bolts to break, while outlining a pair of options to surmount the problem. They also laid out a plan to determine whether similar rods would remain at the same location, the pier at the connection of the Self-Anchored Suspension Span and Skyway portion of the bridge.

At issue are two sets of 3-inch diameter rods, ranging in length from 9 feet to 24 feet. They were manufactured in the United States to lock down seismic devices onto a concrete cap beam beneath the road-decks at the eastern foundation.

Failure of the bolts, and their inaccessible location in a tight space between the road deck and the pier below, will require an engineering solution that provides the same amount of holding or clamping strength as originally sought from the bolts.

Engineers are moving forward on a pair of solutions, both of which clasp around the giant steel hardware pieces and affix the road deck firmly to the pier. One option, a steel collar, is simpler to fabricate, but requires more complicated work on the cap beam below. The other, a steel saddle, offers the opposite set of challenges, a more complicated construction, but less intrusion into the concrete beam below.

TBPOC members hoped to have enough information about the two options to present one at their next scheduled public briefing May 8.

Meanwhile, the investigation into the bolts is ongoing.

The high-strength steel bolts, known technically as threaded connector rods, were manufactured and delivered to the bridge in two sets or batches. First, a set of 96 rods was delivered in 2008 (known as the 2008 rods), followed two years later, by a batch of 192 rods (known as the 2010 rods).

Between March 8 and March 15 of 2013, 32 of 96 rods from the 2008 batch broke a number of days after they were tightened into place. Workers loosened the nuts on the remaining 64 rods, relieving pressure and possibly preventing further failures.

Engineers and materials scientists identified a phenomenon known as hydrogen embrittlement as the cause of the breakages. Hydrogen embrittlement, a documented risk to high-strength steel, requires three factors to cause failure: hydrogen, tension, and susceptibility, that is, something in the composition of the steel that makes it vulnerable to the ubiquitous element hydrogen.

The TBPOC, comprised of the leaders of Caltrans, the California Transportation Commission, and the Bay Area Toll Authority, are undertaking an exhaustive scientific investigation to determine exactly what it was about those 96 bolts that made them susceptible.

Many theories have emerged, but consensus has not yet been reached. At present, evidence seems to point to the nature of the steel itself, the extent to which it lacked homogeneity, and the lack of a testing regimen beyond Caltrans and ASTM standard testing that might have identified the risk. Selecting such hard steel posed risks according to construction standards in use in North America. Special precautions were taken to address those risks, as recommended by industry standards, but, at least in the case of the 96 bolts from 2008, those precautions were inadequate.

That the bolts from 2008 are unserviceable is beyond a doubt. But a conclusion has not yet been reached whether the precautions taken in the fabrication of the 2010 bolts is sufficient to use them on the bridge. To make this determination, TBPOC has placed the 2010 bolts under the same amount of tension as the 2008 bolts, and will remove a sampling of them for destructive metallurgical analysis. Engineers want to know whether there is a meaningful difference between the two batches before deciding whether the 2010 bolts can be put into service.

The investigation continues to follow the mandate laid out in a memorandum from Director of Caltrans Malcolm Dougherty, dated March 29, 2013, and titled "Bay Bridge E2 Connector Rods." That memorandum lays out a 10-step process to investigate the cause while seeking a solution.

One of the first steps called for in this investigation is an examination of the documentation of testing conducted during manufacture. Those documents have been public for weeks and have brought forward many thoughtful theories and have provided information for experts to provide added insight into the investigation.

These records detailed the fact that some of the facilities where the bolts were produced were given "contingent passes" by Caltrans inspectors. But it was later shown that they were given complete approval before fabrication began. The documents also noted that the 2008 bolts, due to record-keeping errors, received two heat treatments, but although that may have altered some of their

characteristics, experts say that alone would not explain the level of susceptibility that lead to the breakages. The documents also showed that the 2008 rods, the ones that failed, were delivered to the job site before Caltrans quality tests were complete, and that some tests were slightly out of range. Again, although noteworthy now, experts say none of these things alone, and possibly not in combination, would provide a satisfactory explanation. But the test numbers have provided metallurgists with information from which they have identified additional testing and to aid in the ongoing analysis.

On May 8, TBPOC members expect to present an engineering solution and sort out what they will do with the 2010 rods.